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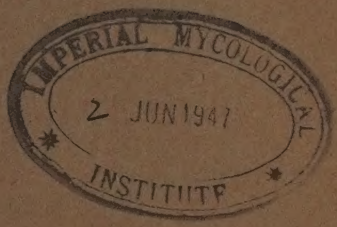

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MATHÉMATIQUES

QUELQUES PROCÉDÉS DE LA RÉSOLUTION DES ÉQUATIONS FONCTIONNELLES LINÉAIRES PAR LA MÉTHODE D'ITÉRATION

Par N. GERCEVANOFF, membre-correspondant de l'Académie

L'équation fonctionnelle linéaire quelconque peut se mettre sous la forme

$$Af(\varphi)+f(x)=\Phi \qquad (1)$$

où A, φ, Φ sont des fonctions données en x, f — une opération à déterminer. Appelons φ «le noyau de l'équation (1)». Pour abréger le language nous exprimerons les fonctions A, f, Φ etc., dans lesquelles x est substitué par φ, au moyen de la notation correspondante: A_1, f_1, Φ_1 etc. Or, la substitution de φ à la place de x dans l'équation (1) nous désignerons comme «l'itération de l'équation (1) par rapport au noyau φ».

1) Nous allons démontrer que la résolution de (1) peut être toujours représentée par une formule explicite, pourvu que φ soit une fonction réfléchie, vérifiant la condition $\varphi_n=\varphi_{n+2}$, où n est l'index d'itération; telles sont les fonctions $a-x$, $\frac{a}{x}$, $\sqrt{a^2-x^2}$ etc.

1-er cas. $AA_1=1$, ou $A=\pm 1$.

La résolution s'exprime en forme paramétrique au moyen de deux équations suivantes ([1], [2]):

$$f=\frac{n}{2}[A\Phi_1-\Phi]+\Phi t+A\Phi_1\left(\frac{1}{2}-t_1\right) \qquad (2)$$

$$x=\varphi_n(x_0)$$

où x_0 est une constante arbitraire, t — une fonction arbitraire en x.

En effet, la substitution de φ à la place de x dans (2) donne

$$f_1=\frac{n+1}{2}[A_1\Phi-\Phi_1]+\Phi_1 t_1+A_1\Phi\left(\frac{1}{2}-t\right). \qquad (3)$$

On voit que les expressions (2) et (3) satisfont au (1).

Exemple:

$$xf\left(\frac{1}{x}\right)+f(x)=p \quad (p=\text{const}). \qquad (4)$$

$$x=x_0^{(-1)^n}. \qquad (5)$$

$$f=\frac{n}{2}[px-p]+pt+px\left(\frac{1}{2}-t_1\right). \qquad (6)$$

En éliminant n entre (5) et (6) on trouve

$$f(x)=\frac{p}{2}\left[\frac{\ln\ln x}{\ln(-1)}+C\right](x-1)+p(t-t_1x)+\frac{px}{2}. \qquad (7)$$

2-me cas. A est une fonction quelconque. On parvient au 1-er cas en prenant la somme de l'équation (1) et la même équation itérée par rapport au noyau φ, ce qui donne

$$\frac{A+1}{A_1+1} f_1 + f = \frac{\Phi + \Phi_1}{A_1+1}. \tag{8}$$

Vu que la résolution de (8) est une condition nécessaire à satisfaire l'équation (1), mais non suffisante, il faut déterminer strictement la fonction arbitraire t par la vérification de l'équation (1).

Exemple:

$$xf(1-x) + f(x) = p \quad (p = \text{const}). \tag{9}$$

En transformant cette équation on écrit

$$\frac{x+1}{2-x} f(1-x) + f(x) = \frac{2p}{2-x} \tag{10}$$

et, d'après (2), $f = \frac{2p}{2-x}\left[t - t_1 + \frac{1}{2}\right]$; en introduisant cette expression en (9) nous obtenons

$$t - t_1 = \frac{1}{2} \cdot \frac{1-2x}{x^2-x+1}, \quad \text{d'où} \quad f(x) = p\,\frac{1-x}{x^2-x+1}.$$

2) Les expressions ci-dessus sont des solutions particulières. Or, la solution générale est $f + \omega$, où ω est une solution de l'équation réduite

$$A\omega(\varphi) + \omega(x) = 0. \tag{11}$$

On peut la ramener à la forme (1) par transformation logarithmique et obtenir la résolution en vertu de (2). Cette résolution peut être à son tour généralisée en multipliant ω par Ω, telle que $\Omega(\varphi) = \Omega(x)$; la détermination de Ω est exposée dans notre Note précédente [1].

C'est ainsi, par exemple, que la solution générale de l'équation (4) se forme en ajoutant au (6) l'expression $\omega(x) = \Omega\sqrt{x}\,x^{u-u_1}(\ln x)^{\frac{k}{m}}$, où u est une fonction arbitraire en x, k et m sont des entiers impairs.

3) Quelquefois la mécanique appliquée présente des équations fonctionnelles, qui renferment la dérivée de la fonction inconnue

$$Mf' + Nf + Pf_1 + Qf_1 = R, \tag{12}$$

$M, N, \ldots, R$ étant des fonctions en x.

La résolution s'obtient par l'intégration de l'équation

$$f' + af = b, \tag{13}$$

a et b étant des fonctions en x, que l'on détermine par la méthode suivante. En prenant la combinaison linéaire de l'équation (13) et sa transformation itérative par rapport au noyau φ, on arrive à

$$Mf' + Maf + Pf_1' + Pa_1 f_1 = Mb + Pb_1. \tag{14}$$

En comparant les coefficients de (12) et (14), on trouve

$$a = \frac{N}{M}, \qquad a_1 = \frac{Q}{P}, \tag{15}$$

$$Mb + Pb_1 = R. \tag{16}$$

La parité de a et a_1 introduit une sujétion qu'on peut écrire

$$\frac{Q}{P} = \frac{N_1}{M_1} \tag{17}$$

et dont on peut s'affranchir, lorsque le noyau φ est une fonction réfléchie, grâce à l'artifice suivant.

4) Écrivons la somme de l'équation (12) et de sa transformation itérée

$$(M+P_1)f'+(N+Q_1)f+(P+M_1)f_1+(Q+N_1)f_1=R+R_1. \qquad (18)$$

Les coefficients de l'équation (18) satisfont au (17). Puisque (18) est une conséquence de (12), il faut vérifier l'équation (12) en déterminant conformément la fonction arbitraire, qui entre dans la résolution de (18).

Exemple:

$$f'(x)+xf(-x)=p, \qquad (19)$$

$$f'-xf+f_1'+xf_1=2p \qquad (20)$$

$$a=-x;\ b+b_1=2p;$$

$$b=p+2p(t-t_1).$$

En intégrant (13)

$$f=pe^{\frac{x^2}{2}}\int e^{-\frac{x^2}{2}}dx+e^{\frac{x^2}{2}}\int 2p(t-t_1)e^{-\frac{x^2}{2}}dx+Ce^{\frac{x^2}{2}}.$$

En introduisant cette expression en (19) on détermine $C=0$ et $t-t_1=$ $=C_1\frac{1}{2p}\ xe^{-\frac{x^2}{2}}$, et la résolution de (19) sera

$$f(x)=pe^{\frac{x^2}{2}}\int e^{-\frac{x^2}{2}}dx-C_1e^{-\frac{x^2}{2}} \quad (C_1-\text{constante arbitraire}).$$

5) L'équation à deux noyaux φ et ψ

$$Mf'(x)+Nf(x)+Pf'(\psi)+Qf(\varphi)=R$$

est réductible à une équation fonctionnelle ordinaire, si φ est une fonction réfléchie et, de plus, $N=\pm Q_1$.

Exemple (tiré de la théorie de l'élasticité)(1):

$$\frac{1}{2}f(x)-\frac{1}{2}f(-x)-xf'(ix)=p \quad (p=\text{const}). \qquad (21)$$

En éliminant la fonction f au moyen de l'itération par rapport au noyau $(-x)$ nous arrivons à

$$f'(ix)-f'(-ix)=-\frac{2p}{x}, \text{ et en posant } ix=u$$

$$f'(u)=\frac{ip}{u}+\frac{2pi}{u}(t_1-t);\ f(u)=ip\ln u+2pi\int\frac{t_1-t}{u}du+C;$$

si, en outre, nous nous contenterons de la valeur t telle que $t_1-t=\text{const}=B$, il faut introduire f dans l'équation (21), d'où l'on tire $B=\frac{4-m\pi}{2(m\pi-2)}$, m étant un entier impair et $f(x)=\frac{2ip\ln x}{m\pi-2}+C$ (2); $C-$constante arbitraire.

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MATHÉMATIQUES

LES ESPACES DE FINSLER À DEUX DIMENSIONS À GROUPES D'HOLONOMIE FINIS ET CONTINUS

Par V. WAGNER

(Présenté par S. L. Soboleff, de l'Académie, 11. I. 1943)

Soit $L(\xi^\alpha, d\xi^\alpha)$ la fonction métrique d'un espace de Finsler à deux dimensions F_2. Dans l'espace euclidien affin-tangent E_2, qui correspond à chaque point du F_2, la fonction $L(\xi^\alpha, d\xi^\alpha)$ détermine une métrique minkowskienne. La longueur x d'un vecteur x^α dans l'E_2 tangent correspondant au point ξ^α est

$$x = L(\xi^\alpha, x^\alpha). \tag{1}$$

Le transport parallèle des vecteurs suivant une courbe $\xi^\alpha = \xi^\alpha(t)$ dans F_2 est défini par le système des équations différentielles

$$\frac{dx^\alpha}{dt} + \Gamma^\alpha_\beta \frac{d\xi^\beta}{dt} = 0 \tag{2}$$

où, comme il est connu [1],

$$\Gamma^\alpha_\beta = \frac{\partial G^\alpha}{\partial x^\beta}; \quad G^\alpha = \frac{1}{4} a^{\alpha\lambda}\left(x^\omega \frac{\partial^2 L^2}{\partial \xi^\omega \partial x^\lambda} - \frac{\partial L^2}{\partial \xi^\lambda}\right) \tag{3}$$

et $a_{\alpha\beta}$ est le tenseur métrique du F_2.

Si nous considérons le vecteur x^α comme le rayon-vecteur d'un point dans E_2 tangent, nous obtiendrons, à l'aide du transport parallèle des vecteurs, les représentations ponctuelles des E_2 tangents un sur l'autre suivant une courbe dans F_2. Introduisons dans les E_2 tangents le système des coordonnées curvilignes x, u, où x est la longueur du rayon-vecteur et u est un paramètre déterminant la direction du rayon-vecteur:

$$x = L(\xi^\alpha, x^\alpha) \qquad u = u(\xi^\alpha, x^\alpha) \tag{4}$$

où $u(\xi^\alpha, x^\alpha)$ est une fonction positivement homogène de degré zéro par rapport aux x^α. En résolvant les équations (4) pour x, u nous obtenons

$$x^\alpha = x l^\alpha(\xi^\alpha, u) \tag{5}$$

où $l^\alpha(\xi^\alpha, u)$ est le rayon-vecteur de l'indicatrice du F_2. Dans les systèmes des coordonnées introduits les équations (2) deviennent

$$\frac{dx}{dt} = 0; \qquad \frac{du}{dt} + \overset{(u)}{\Gamma}_\beta \frac{d\xi^\beta}{dt} = 0, \tag{6}$$

où

$$\overset{(u)}{\Gamma}_\beta = \overset{(u)}{\Gamma}_\beta(\xi^\alpha, u) = -(\nabla_\beta u)_{x^\alpha = l^\alpha(\xi^\lambda, u)} \tag{7}$$

$\nabla_\beta u = \frac{\partial u}{\partial \beta \xi} - \Gamma^\omega_\beta \frac{\delta u}{\partial x^\omega}$ étant la dérivée covariante du scalaire u.

Il résulte des équations (6) que, sous la représentation des E_2 tangents, la longueur du rayon-vecteur est conservée et, par conséquent, pour étudier ces représentations il suffit d'étudier les représentations des indicatrices l'une sur l'autre. En représentant les E_2 tangents suivant les cycles différents, partant d'un point O et y revenant nous obtenons le groupe d'holonomie du F_2. En général, le groupe d'holonomie du F_2 est un groupe continu infini, mais en certains cas particuliers ce groupe peut être continu fini. Nous nous proposons de déterminer la caractéristique invariante pour les F_2 à groupes d'holonomie finis.

Considérons le groupe d'holonomie comme un groupe des transformations ponctuelles sur l'indicatrice. Supposons que chaque point du F_2 est lié au point O par une courbe donnée. Choisissons le paramètre u sur les indicatrices de manière qu'en représentant l'indicatrice attachée au point O sur l'indicatrice attachée au point M quelconque suivant la courbe donnée, nous obtiendrons que les points correspondants correspondent à la même valeur du paramètre. Il est évident que le choix du paramètre sur l'indicatrice attachée au point O est complètement arbitraire. Nous appelons le paramètre ainsi choisi le paramètre canonique. Par rapport au paramètre canonique la représentation des indicatrices attachées aux points M_1 et M_2 quelconques liés par une certaine courbe et la transformation du groupe d'holonomie correspondant au cycle OM_1M_2O sont déterminées analytiquement par la même équation (3).

Supposons que le groupe d'holonomie sur l'indicatrice est généré par les transformations infinitésimales $X_i f = \underset{i}{a}(u)\frac{df}{du}$, $i = 1, \ldots, r$. En ce cas les coefficients $\overset{(u)}{\Gamma}_{\beta}$ rapportés au paramètre canonique doivent avoir la forme

$$\overset{(u)}{\Gamma}_{\beta} = \sum_{i=1}^{r} \overset{i}{w}_{\beta}(\xi^{\alpha}) \underset{i}{a}(u) \tag{8}$$

où $\overset{i}{w}_{\beta}(\xi^{\alpha})$ sont certaines fonctions des ξ^{α}. Il résulte des équations (7) et (8) que le paramètre canonique doit satisfaire aux équations différentielles

$$\nabla_{\beta} u + \sum_{i=1}^{r} \overset{i}{w}_{\beta}(\xi^{\alpha}) \underset{i}{a}(u) = 0. \tag{9}$$

Comme il est connu, tous les groupes finis des transformations ponctuelles dans une variété à une dimension sont localement semblables au groupe des transformations projectives sur la droite ou à ses sous-groupes. Ainsi nous avons trois cas à considérer:

1) Le groupe d'holonomie du F_2 est un groupe à un paramètre. Les équations (9) deviennent

$$\nabla_{\beta} u + \overset{1}{w}_{\beta}(\xi^{\alpha}) = 0 \tag{10}$$

et seront équivalentes aux équations

$$\nabla_{\beta} v = \varepsilon \nabla_0 A t_{\beta} v, \qquad \frac{\partial u}{\partial \theta} = v \tag{11}$$

où θ est la longueur centro-affine d'arc d'indicatrice, t_{α} sont les composants covariants du vecteur-tangent d'indicatrice $t^{\alpha} = \frac{\partial l^{\alpha}}{\partial \theta}$; $\varepsilon = a_{\gamma\beta} l^{\gamma} l^{\beta} = \pm 1$; A est la courbure centro-affine d'indicatrice et $\nabla_0 A = l^{\beta} \nabla_{\beta} A$.

Les conditions d'intégrabilité du (11) sont

$$Q_{\beta} = 0 \tag{12}$$

où

$$Q_{\beta} = \varepsilon \nabla_{\beta} \left(\frac{\nabla_0 \nabla_0 A}{K} \right) - \nabla_0 A \frac{\nabla_0 \nabla_0 A}{K} t_{\beta} - \varepsilon \frac{\partial (\nabla_0 A t_{\beta})}{\partial \theta} \tag{13}$$

et K est le scalaire de la courbure du F_2.

Ainsi l'équation (12) est la condition nécessaire et suffisante pour que le groupe d'holonomie du F_2 soit à un paramètre. Comme une sous-classe remarquable de ces F_2 nous notons les espaces de Landsberg caractérisés par la condition $\nabla_0 A = 0$, pour lesquels θ peut être choisi comme le paramètre canonique.

2) Le groupe d'holonomie du F_2 est un groupe à deux paramètres. Les équations (9) deviennent

$$\nabla_\beta u + \overset{1}{w}_\beta(\xi^\alpha) + \overset{2}{w}_\beta(\xi^\alpha)\, u = 0 \tag{14}$$

et sont équivalentes aux équations

$$\nabla_\beta v = \varepsilon \nabla_0 A t_\beta v + \varepsilon \frac{\partial (\nabla_0 A t_\beta)}{\partial \theta}; \quad \frac{\dfrac{\partial^2 u}{\partial \theta^2}}{\dfrac{\partial u}{\partial \theta}} = v. \tag{15}$$

Les conditions d'intégrabilité donnent

$$Q_\beta v + \frac{\partial Q_\beta}{\partial} - 2\varepsilon \frac{\nabla_0 \nabla_0 A}{K} Q_\beta = 0. \tag{16}$$

En résolvant une des équations (15) pour v et en substituant v dans les équations (15) nous obtenons la condition nécesaire et suffisante pour que le groupe d'holonomie du F_2 soit à deux paramètres.

3) Le groupe d'holonomie du F_2 est un groupe à trois paramètres. Les équations (9) deviennent

$$\nabla_\beta u + \overset{1}{w}_\beta(\xi^\alpha) + \overset{2}{w}_\beta(\xi^\alpha)\, u + \overset{3}{w}_\beta(\xi^\alpha)\, u^2 = 0 \tag{17}$$

et sont équivalentes aux équations

$$\nabla_\beta v = 2\varepsilon \nabla_0 A t_\beta v + \varepsilon \frac{\partial^2 (\nabla_0 A t_\beta)}{\partial \theta^2}; \quad \frac{\dfrac{\partial^3 u}{\partial \theta^2}\dfrac{\partial u}{\partial \theta} - \dfrac{3}{2}\left(\dfrac{\partial^2 u}{\partial \theta^2}\right)^2}{\left(\dfrac{\partial u}{\partial \theta}\right)^2} = v. \tag{18}$$

Les conditions d'intégrabilité sont

$$2Q_\beta v + \frac{\partial^2 Q_\beta}{\partial \theta^2} - 3\varepsilon \frac{\nabla_0 \nabla_0 A}{K} \frac{\partial Q_\beta}{\partial \theta} - 3\varepsilon \frac{\dfrac{\partial \nabla_0 \nabla_0 A}{\partial \theta} + A \nabla_0 \nabla_0 A}{K} Q_\beta = 0 \tag{19}$$

et nous pouvons obtenir de la même façon que dans le cas précédent la condition nécessaire et suffisante pour que le groupe d'holonomie du F_2 soit à trois paramètres.

Université de Saratov.

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ASTRONOMY

THE OUTER SOLAR CORONA AT THE TOTAL ECLIPSE SEPT. 21, 1941

By B. FESSENKOFF, Member of the Academy

The total eclipse of Sept. 21, 1941 was photographed under my direction at the Kamenskoe Plateau Station (near Alma-Ata) with a wide angle camera of 45 cm focal length. The Saphir Boyer object-glass with an aperture of 100 mm covers nearly 1000 square degrees of the field. Great attention was given to exact focusing which was achieved by different methods. Moreover, the distribution of illumination over the field of the camera was calculated and the results checked experimentally.

It was found that the correction factor is quite insignificant near the optical axis, but becomes noticeable at a distance of some 12 cm—the limit of our measurements. Table 1 contains the correction factor including the effect of oblique incidence of rays and screening by the diaphragms connected with the objective lenses.

Table 1

1	2	3	4	5	6	7	8	9	10	11	12 cm
0	2	4	11	20	31	43	55	69	84	97	114×10^{-3}

(the corrections are to be referred to the logarithms of intensity).

The aim of the investigation was to determine the shape and dimension of the outer corona, as well as to ascertain the possible existence of the Zodiacal Light in the closest vicinity of the Sun. Consequently, I was anxious to eliminate as completely as possible the influence of the atmospheric scattered light, depending mostly on the auroral ring near the horizon, and also the halation effect of the inner corona.

First, the photometric reduction curve had to be determined. With this in view the sky at a point symmetrical to the Sun was exposed on identical plates (Agfa Sternplatten) with an appropriate tubular photometer. As a mean I have obtained from a number of separate curves the following relation between the readings of Hartmann's microphotometer σ and the corresponding brightness J:

Table 2

$\lg J$	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
σ	15.0	16.6	18.3	20.0	21.8	24.0	26.4	28.7	31.0
$\lg J$	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	
σ	33.4	35.9	38.4	40.9	43.4	45.9	48.4	50.0	

The eclipse plates of 24×30 cm measured with Hartmann's microphotometer may then serve to trace a system of isophotes over a large portion of the sky including the horizon. One clearly sees that the sky brightness gradually increases towards the horizon and somewhat towards the East. The closed system of iso-

photes characterizing the solar corona loses its symmetrical shape and becomes more elongated towards the horizon at a certain distance from the Sun.

It may be assumed that the general distribution of brightness over the sky during the eclipse is chiefly due to the intensive auroral ring near the horizon; the corona itself being a secondary factor. Therefore, neglecting for a moment the presence of the corona, one may determine the isophotes as they would be if produced by the auroral ring alone. The differences between these isophotes and those actually observed represent the corrections which should be taken into account when measuring the brightness of the outer corona. It is seen that the sky brightness, depending on the influence of the auroral ring, varies very markedly over the field of the outer corona (approximately within 10%). Taking this correction into consideration, the first step can be taken to determine the real distribution of brightness in the corona. The corresponding isophotes appear to be quite symmetrical around the Sun at least at a distance of four solar diameters; but with the decreasing brightness their shape becomes, by degrees, more spherical.

Indeed, the ratio m of the axes of symmetry is the following:

Table 3

m...0.74	0.80	0.83	0.82	0.86
Isophote...2.0	1.0	0.58	0.41	0.28

Most of the outer isophotes are elongated towards the horizon and this deformation is produced by the halation effect of the inner corona. In fact, the inner corona which forms a narrow ring around the Sun gives the same distribution of brightness all over the sky like the Sun itself, but reduced nearly a million times. The colour of the corona being similar to that of the Sun, the ratio of halation k is exactly the same as the ratio of intensity of the same sources. Consequently, at a comparison with a standard screen of a known reflecting power, directly illuminated by the Sun, the observation of the brightness of the sky at different points provides a simple means of accounting for the above-mentioned effect of halation. Evidently, it is necessary to know the brightness of the sky during the eclipse as compared to the same brightness at full daylight and at the same height of the Sun. With this purpose some special exposures at sky brightness were taken on the day immediately following the eclipse. Therefore reducing the halalion effect from the Sun to the ratio k, one is able to compute the necessary correction.

It is interesting to note that the influence of the inner corona upon the outer is very sensitive at great distances from the Sun, being for instance 11—16% at 1°, and 26—34% at 2° for great and small axes, respectively.

Concluding, the following isophotes are obtained:

Table 4

Brightness in arbitrary units . . .	1.0	0.8	0.6	0.4	0.2
Ratio of axes	0.82	0.80	0.77	0.80	0.81

Therefore the oblateness of the isophotes is the same, being equal to 0.80 at any distance from the Sun. The conception of a spherical shape of the outer corona, put forward by some American astronomers, is not correct.

The Zodiacal Light is totally absent from the eclipse sky in contradiction to the indication of some Japanese observers. The above-described method provides a simple means of judging the real form of the corona, as it might be observed without our atmosphere.

Institute of Astronomy and Physics.
Alma-Ata.

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TECHNICAL PHYSICS

BORIC UVIOL GLASS FOR BACTERICIDAL LAMPS

By V. P. DANILOV and Z. A. JOFFE

(Communicated by S. I. Wawilow, Member of the Academy, 2. III. 1943)

Low pressure mercury lamps with bactericidal power are now being extensively used abroad, especially in USA, for sanitation purposes (1). Naturally enough, the use of similar lamps in this country on a vast scale, particularly in war time, is very desirable.

The characteristic feature of a bactericidal lamp is that it is made of glass transmitting the radiation of the resonance line of mercury with a wave-length of 254 mμ.

In the whole short-wave ultraviolet region this radiation has the strongest bactericidal action. At the same time such lamps should practically entirely absorb all the shorter waves of the spectrum which are known to have a harmful effect upon the organism of man.

In working out the constitution of a glass that should meet these requirements we had to work it out of materials that could be obtained without special preliminary processes. This condition excluded the use of any silicate and borosilicate uviol glass, because for their preparation a highly pure sand is necessary.

As for phosphate glass, it is inadaptable on account of the separation of phosphorus under the action of ultraviolet rays with consequent loss of transparency.

Moreover, many phosphate glasses will not fuse with the metal employed for the preparation of the lamp or with glass made on no phosphate basis.

A solution of this problem was found in using boric acid as the basic ingredient of the glass.

According to Schmidt, Gelhoff and Thomas (2), glasses containing certain oxides of heavy metals, such as lead oxide or iron oxide, fail to transmit the short waves of the ultraviolet. An especially harmful admixture in this respect is iron oxide, which, if present in the glass in quantities exceeding 0.01%, practically absorbs the whole of the spectrum region required for bactericidal lamps.

As raw materials for the manufacture of uviol glass we used boric acid, barium carbonate, aluminium hydroxide and soda with a possibly low content of iron oxide.

The total content of F_2O_3 in a prepared glass was not above 0.01%.

In working out the composition of the glass, the objectives strived for were, first, that the coefficient of dilatation of the glass be near to that of platinide, employed as conductor in the lamp; secondly, the glass should possess sufficient chemical resistance for in-door use of the lamp. Of the many compositions inve-

stigated by us we have chosen two satisfying the above requirements (see the table).

Composition of Boric Uviol Glasses

Nos. of glasses	Content in per cent			
	B_2O_3	Al_2O_3	BaO	Na_2O
1	55	17.5	20.0	7.5
2	60	15.0	25.0	—

With regard to the properties essential from the viewpoint of glass manufacturing the two glasses differ very little from each other. Both are easily fusible (the melting is carried on at 1150° C), and characterized by a wide softening interval («long glasses»). The working temperature is 850 to 900° C. Under laboratory conditions the duration of the melting process is not above 2 hours. Crystallization tests have shown that these glasses are harder to crystallize than the window glass of Fourcaut.

Being readily fusible, they require some special experience from the blower when worked on a blow-torch. The disappointing circumstance with all of the boron glasses investigated by us, the two above-mentioned inclusive, is that they are prone to get turbid when worked on the blow-torch, for instance in preparing the butt ends of the lamp. The turbidity seems to be caused by gases dissolved in the glass, which evolve on heating. In the case of the glasses selected by us this drawback can be avoided, for they fuse well with the No. 23 glass of the «Druzhnaia Gorka» works, which can be used in making the butt parts of the lamp.

Respecting the properties of the proposed glasses, it may be remarked that the first glass is more resistant chemically, while the second, being more hard to melt, is better fitted to be worked on the torch.

In the course of our investigation we have revealed certain particulars in the influence of individual oxides on the properties of boron glass.

Effect of Boric Acid. We varied the content of B_2O_3 in different glasses from 40 to 60%. With increasing content of B_2O_3 the glass becomes less resistant chemically, but its other properties are affected favourably. In the first place, the increase of the B_2O_3 content increases the softening interval, such glass is better adaptable to working. In the second place, the tendency of the glass to crystallization is the weaker, the higher the content of B_2O_3. Finally, according to literary data [3], acid glasses are less liable to polarization in the course of the service of the lamp than are more basic glasses. Furthermore, the preparations of boric acid contain very little iron or, at any rate, may easily be freed from it, which is most essential for a good transmission of the far ultraviolet. Yet, an increase of the B_2O_3 content beyond 60% does not appear expedient, because then the chemical resistance of the glass is greatly diminished.

Effect of Barium Oxide. The content of BaO varied from 20 to 40%. The barium oxide was introduced in the glass in order to increase its chemical resistance. Although the least effective in this respect among the other alkaline earth oxides, we were compelled to use it because the preparations of barium: $BaCO_3$ and, particularly, $Ba(NO_3)_2$ contain comparatively little iron [0.005% Fe_2O_3 in $Ba(NO_3)_2$]. The introduction of more than 40% BaO cannot be recommended, since a «short» glass of salt-like character will thereby be produced.

Effect of Aluminium Oxide. The rôle of aluminium oxide as ingredient is to increase the chemical resistance of the glass and the interval of softening. Experiments have shown that one must not introduce more than 20% of aluminium oxide in the glass, lest the latter should show a marked tendency to crystallization. Besides, if the glass is high in Al_2O_3, there is a crust forming

on its surface during melting, probably because the charge comes off in layers and a boron-aluminium hard-fusing glass forms on the surface. We used the hydroxide of aluminium in the charge, because the oxide is sparingly soluble in boric acid and gives an opalescent effect. It is well to remark in addition that the preparations of aluminium oxide not unfrequently contain considerable amounts of Fe_2O_3 (0.021%) and can be freed from iron only with great difficulty.

Effect of Sodium Oxide. Sodium oxide was introduced in the glass in order to lessen its tendency to crystallization; especially so in the case of glasses containing Al_2O_3 in considerable quantities. In fact, a glass with Na_2O is very little liable to crystallization. The optimal content of Na_2O, according to our experience, does not exceed 7.5%.

Turning to the question of industrial melting of glasses for bactericidal lamps, it should be noted that the ordinary pottery, e. g. that used in manufacturing optical glass, will not fit here on account of its high content of iron oxide (above 1%).

In view of this, special coatings with a low content of iron oxide (0.030% Fe_2O_3) were designed in this laboratory for the melting pots. The coating prevented the iron oxides contained in the walls of the pot from being dissolved in the glass.

At present these coatings are being tried under industrial conditions.

The boric glass fused in crucibles thus protected showed no considerable reduction of transparency to the far ultraviolet, as compared to the glass fused in a platinum crucible.

Test-lamps made of this glass showed for $\lambda=254$ mμ a maximum transmission of about 40% in the working thickness of the lamp. This compares very favourably with the 20% transmission for the same wave-length which an American specimen in our possession was able to display. On preliminary tests in the clinique these lamps have been found to have a strong bactericidal power and be also useful for therapeutic purposes.

Coloured Glass Laboratory.
State Optical Institute.

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METALLURGY

NEW THEORY OF QUALITATIVE ESTIMATION OF METALLURGIC COKE

By K. I. SYSKOV

(Communicated by N. P. Chizhevsky, Member of the Academy, 15. IV. 1943)

The theory outlined below is concerned with the estimation of the quality of coke from its physical-chemical and physical properties.

Blast furnaces have their productive capacity determined by a great many factors. Among the main of them are the quantity of the air blown in and the regularities of working. On the amount of blast depends the intensity of the process.

The raw materials entering into the composition of the charge have certain characteristics controlling the blast regime of the furnace, any of which can be taken to indicate the quality of the respective material. Starting from this point, the author, in the case of metallurgic coke, has taken for the indicator of its quality those characteristics of its physical-mechanical properties which control the resistance of lump coke to the gas movement. These characteristics can arbitrarily be described as indicators of the intensity of a blast furnace process. In case powerful blowing engines are available, air can be sent to the furnace in very great quantities, whereby the process within the furnace will be greatly intensified.

If, however, the coke offers considerable resistance to the movement of gases, the blowing-in of great quantities of air to the furnace necessitates the use of high pressure. As high, indeed, as to fall in the same order with, or even exceed, the counterpressure (weight) of the entire column of the materials the furnace is loaded with. This can cause scaffolding of the material in the furnace and the latter will be working with «slips». On the other hand, the rate of gas movement will increase with the pressure of the blast and there will be an appreciable loss of ore in the form of the escaping fire bar dust. It will be obvious that for the good work of the furnace a good permeability of the charge layer to gases is essential (no deposits, no excessive carrying off of fire bar dust etc.).

The work of the furnace is also more or less regular according as the sinking of the materials to the hearth across the cross-section of the furnace is more or less uniform. This in turn is controlled by the volume of the carbon combustion zone.

And this zone has its extension related to the rate of combustion of coke in the region of the tuyeres.

On this consideration the characteristic of the rate of combustion of coke (surface area of coke lumps on the tuyeres, etc.) are taken by the author for quality indicators and freely described as indicators of the oxidizing zone volume.

Thus, the quality indices of the coke fall into two groups:

1. The indices of the resistance of the coke (of the intensity of the blast furnace process).

2. The indices of the volume of the carbon combustion zone (of the working regularity of the furnace).

The resistance offered by the materials to the movement of gases in the furnace does not depend upon the presence of coke alone, but also upon the mesh (granulometric) composition of the burden, upon the process of slag formation and a number of other factors. As the coke takes up nearly three fourths of the furnace volume, one may, other conditions being equal, take the resistance of the whole column of materials to be equivalent to that of an equal column of coke. In order to evaluate the resistance of coke, its condition in the furnace should be known.

Of what we actually have a more or less clear understanding at present is the condition of the coke before the furnace and in the region of the hearth ([1]). So the author in the first stage of his work bases the estimate on the state of the coke, while approaching the furnace and the tuyeres. Later on, with the respective data at hand, it will be necessary to estimate the state of the coke at all levels of the furnace and also to appraise the influence of the burden on the resistance to gas movement.

In deriving the expressions for the new indices of coke quality use may be made of the same equations already established in hydrodynamics and physical chemistry.

Loss by resistance can, for a layer of lump materials having a unit height, be expressed by means of the following equations:

$$h_d = \frac{v^2\gamma_g}{2g} = \frac{8}{\pi^2 g}\,\frac{Q_g^2\gamma_g}{D^4}\,h_{dk}$$

$$h_s = h_c + h_e = \frac{8}{\pi^2 g}\,\frac{Q_g^2\gamma_g}{D^4}\,h_{dk}h_{sk}$$

$$h_g = h_d + h_s = \frac{8}{\pi^2 g}\,\frac{Q_g^2\gamma_g}{D^4}\,h_{dk}(h_{sk}+1) = \frac{8}{\pi^2 g}\,\frac{Q_g^2\gamma_g}{D^4}\,h_{gk}$$

where v is velocity of the gas; γ_g, its density; h_c and h_e, loss of pressure due to friction and local resistances, respectively; h_d, h_s and h_g, losses in dynamic, static and total pressure of gas; Q_g, gas volume passing a given cross-section of diameter D; h_{dk}, h_{sk} and h_{gk}, factors varying only with the properties of the coke. They have been taken to indicate the qualities of the coke, because they control the loss of dynamic, statik and total pressure of gas, respectively.

For the volume of the oxidation zone the author has derived the following equation ([1]):

$$V = \frac{0.21\cdot Q_{0.760}\cdot\sigma}{K_D(C_s - C)}\cdot\frac{1}{\gamma_b S} = 0.21\cdot K\cdot Q_{0.760}\cdot E_k.$$

Here $Q_{0.760}$ is volume of blast reduced to normal conditions; K_D, coefficient of diffusion; σ, thickness of surface film; C_s and C, concentrations of oxygen in the film at the surface of the coke and in the gas phase, respectively; γ_b, bulk weight of coke; S, surface of coke lumps; E_k, volume coefficient of oxidation zone, determined by the properties of coke.

The term $\frac{\sigma}{K_D(C_s - C)}$ is connected with the combustibility of coke, which at high temperatures is nearly equal for all cokes. Therefore until the problem is studied in more detail, qualitative characteristics of the coke affecting the volume of the oxidation zone are expressed by the author by means of the factor E_k defined by the formula:

$$E_k = \frac{1}{S\gamma_b} \simeq \frac{v_{fr} + \delta}{S},$$

where v_{fr} is volume of free space within the coke pile.

In an approximate manner all the above quantities can be expressed by the free space volume between the separate lumps, v_{fr} in dm³/kg, and by their total surface area, S in dm²/kg. In their turn, v_{fr} and S may be computed from the mesh (granulometric) composition of coke. The mesh composition, which characterizes the condition of the coke at a certain level of the surface, is reproduced artificially (without taking samples of the material through tuyeres) in a coke test-apparatus. In the apparatus the destruction of coke is evaluated in terms of the energy required for the artificial reproduction of the most typical condition of the coke.

For computing the qualitative indices of coke the following approximate equations are serviceable (¹):

$$h_{dk} = \frac{1}{F_g} = (\gamma_k - \gamma_b)^{-\frac{4}{3}} \gamma_k^{\frac{4}{3}} = \left(\frac{v_{fr}+1}{v_{fr}}\right)^{\frac{4}{3}};$$

$$h_{sk} = \sigma\left(\frac{Pl}{F}\right) + \sum \xi = 3\sigma\gamma_b^{\frac{1}{3}}\gamma_k^{\frac{2}{3}} + \sum \xi = \frac{3\sigma S}{(v_{fr}+1)\sqrt[3]{v_{fr}^2}} + \sum \xi;$$

$$h_{gk} = (1 + h_{sk})\, h_{dk}.$$

Here F_g is the available cross-section area for the passage of gases; λ_k and λ_b, the apparent and the bulk weight of coke; P, l and F, perimeter length and area of cross-section through channels for the passage of gas; σ and $\sum\xi$, coefficients of friction and of local resistances ($\sigma \cong 0.1$; $\sum\xi = 1$).

As the study is carried further, these expressions for the qualitative indices may be modified and refined. Their fitness for the practical estimation of the quality of coke has been verified by the author on the data of experimental blast furnace meltings carried out by a committee of the USSR Academy of Sciences under the guidance of M. A. Pavlov in the metallurgical plant of Magnitogorsk.

The results of this work are summarized in the adjoined table.

Coke	Period of melts	$p \times 10^5$	Mesh composition of coke measured in the melting department				v_{fr}, dm³/kg	S, dm²/kg	h_{dk}	h_{sk}	h_{gk}	E_k
			> 80	40—80	25—40	< 25						
Sorted . . .	26.X — 5.XI	19.0	21.7	64.7	11.1	2.5	1.145	11.03	2.31	2.41	7.86	0.241
Prokopievka	11.VI — 25.VI	20.5	22.3	61.0	13.5	3.2	1.138	11.48	2.31	2.84	8.05	0.188
Karaganda.	30.VII — 14.VIII	23.3	18.9	63.0	14:8	3.3	1.112	11.75	2.35	2.56	8.36	0.180
Leninsk . .	8.VII — 19.VII	23.8	13.1	63.0	18.5	5.4	1.057	13.05	2.43	2.48	9.31	0.158

When the blast pressure (p) to a unit volume of the hot air blown-in was compared with the coefficient of coke resistance to gas movement (h_{gk}), as computed from mesh composition in the hearth region or from the condition of the coke while not yet in the furnace, it appeared, according to expectations, that these characteristics changed in a single direction. This pointed to the existence of a definite relation between p and h_{gk} and confirmed the correctness of the advanced conception.

The resistance of the particular coke was in accordance with the blast regime of the furnace. The same was true for the working regularity of the furnace. The higher the value of the coefficient E_k, the more regular was the work of the furnace (¹).

Free space between the coke lumps and their surface were computed from the general formulae suggested by the author ([1]). In the present case when the mesh sizes were 25, 40 and 80 mm these formulae looked as follows:

$$v_{fr} = 17a_{>80} + 10.4a_{40-80} + 7.7a_{25-40} + 6.6a_{<25} \text{ cm}^3/\text{kg}$$

$$S = 6a_{>80} + 10a_{40-80} + 18.5a_{25-40} + 48a_{<25} \text{ cm}^2/\text{kg}$$

where $a_{>80}$, a_{40-80}, a_{25-40} and $a_{<25}$ are yields (in per cent) of the corresponding coke classes with lumps measuring >80, 40 to 80, 25 to 40 and <25 mm, respectively.

Thus, estimates of the quality of coke made both from its state in the hearth and from its mesh composition before the furnace have furnished corroborative evidence to the main suggestion of the author, viz., that the quality of a coke should be appraised from its gas permeability. The problem of qualitative estimation of metallurgical coke is of high economic importance. It bears closely upon the adequate choice of coals for coking, on the development of new methods for the estimation of the coking ability of coals, on the extension of the raw material basis of the coke chemistry and, finally, on the proper orientation of prospecting for a coal yielding a good metallurgic coke.

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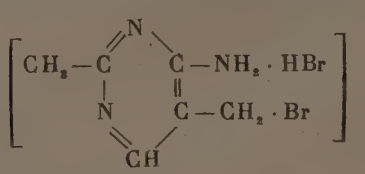
CHEMISTRY

ON THE CHARACTERISTIC OF 2-METHYL-4-AMINO-5-BROMOMETHYL PYRIMIDINE HYDROBROMIDE

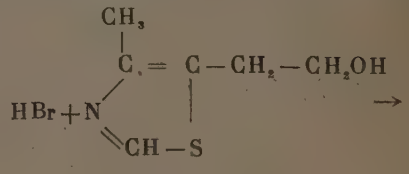
By J. M. SLOBODIN

(Communicated by A. E. Arbusov, Member of the Academy, 4.I.1943)

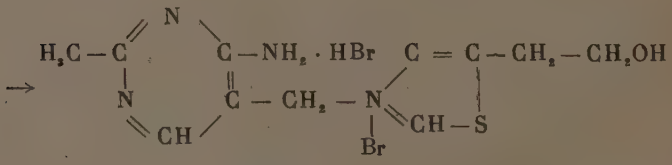
The method recently developed for the synthetic production of vitamin B_1 consists in a separate synthesis of 2-methyl-4-amino-5-bromomethyl pyrimidine hydrobromide (I) and of 4-methyl-5-(β-oxyethyl)-thiazole (II) with their subsequent condensation to a molecule of vitamin B_1 (III):



(I)



(II)



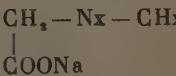
(III)

This condensation, owing to the exceptional mobility of the bromine atom in the group CH_2Br, is accomplished very easily and with a high yield.

While going into the detail of this synthesis, I came across the necessity to have analytical data for the initial 2-methyl-4-amino-5-bromomethyl pyrimidine hydrobromide. And I found that the three bromine atoms of the molecule (I) can be determined by titration with $AgNO_3$ according to Folgart or according to More.

This is a very interesting observation, as in this case it is possible by means of ordinary titration to determine not merely the ionogenic halogen, but the halogen atom connected with the carbon atom by a covalent bond.

Similar facts have been observed by F. J. Rachinsky (private communication) on the titration of halogenated products of condensation of α-amino-acids with aliphatic aldehydes (IV).



(IV)

where x is Br or I.

In this case the titration with $AgNO_3$ determines both of the halogen atoms.

It may be inferred from the above that in the compounds of type (I) and (IV) the covalent carbon-halogen is near to dissociation.

Method of Determination. A portion of the substance (I) about 0.5 g in weight is dissolved in 50—100 cm^3 of water. The solution is added with 2—3 g of precipitated thoroughly washed $CaCO_3$ and with a few drops of K_2CrO_4. Titration with a n/10 solution of $AgNO_3$, as usual. The colour appears distinctly against the white background of $CaCO_3$.

Found %: Br—I) 65.48; II) 65.77; III) 66.01; IV) 65.84.

Calculated for $C_6H_{10}N_2Br_2$%: Br—65.93.

Analysis according to Carius gave coinciding results. This method has been successfully applied to the analysis (I) in preparing vitamin B_1 at the Vitamin Institute.

S. M. Kirov Military
Medical Academy.

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PHYSICAL CHEMISTRY

ON THE THEORY OF COMBUSTION, INFLAMMATION AND EXPLOSIONS*

By N. S. AKULOV

Member of the Academy of Sciences of the White Russian SSR

In this paper the solution of the two main problems of the theory of combustion, inflammation and explosions is given: 1) the determination of the time of retardation of spontaneous ignition, inflammation and explosion as a function of pressure and temperature of the gas mixtures, and 2) the determination of the boundaries of the area of self-inflammation including all the three limits it involves.

Having this purpose in mind, we shall use the equation obtained for the period of retardation of autogenetic reactions in our previous paper (1)

$$\tau = \frac{\Delta\tau_{\alpha\to 0}}{\varkappa\delta - 1}. \qquad (1)$$

The probability of the prolongation of the chain δ can be expressed by means of the number of collisions of the active particle with other particles.

Let Z_a be the relative number of collisions, when the particle enters the reaction, and let Z_i be the number of collisions leading to the desactivation of the particle, without entering the reaction. Then

$$\delta = \frac{Z_a}{Z_a + Z_i}. \qquad (2)$$

Now the relation $\frac{Z_i}{Z_a}$ we have already obtained on the basis of the existing notions on the annihilation of active centres in the volume and on the walls of the vessel (4). We have obtained in this case **

$$\frac{Z_i}{Z_a} = \left(a_2 \frac{T^2}{p^2} + a_3 \frac{p}{T}\right) e^{\frac{E}{RT}}. \qquad (3)$$

Further, the time of the development of the primary link will be inversely proportional to the concentration of active centres, i. e.

$$\Delta\tau_{\alpha\to 0} = \Delta\tau_0 \frac{T}{p}. \qquad (4)$$

Finally, $\varkappa$ in the contemporary theory is accepted as a constant value. Generalizing we shall assume, however, that this value is constant only at low concentrations, but as the concentration of the gas and the number of colli-

* Reported at the Conference of the Mendeleyev Chemical Society 25 June 1942, Alma-Ata USSR.

** A similar expression was obtained by Semenov (3) for β, this being true only when $Z_i \ll Z_a$, because $\beta = 1 - \delta = \frac{Z_i}{Z_a + Z_i}$.

sions grow, it is supposed to obtain an increment, proportional to the number of double collisions. Thus, we obtain:

$$x-1=a_0+a_1\frac{p^2}{T^2}. \qquad (5)$$

This consequence of our assumption is, as we shall see later, quantitatively justified through comparison with the experiment, thus giving the possibility to explain the existence and the character of the third limit of inflammability.

From (1)—(5) we find

$$\tau=\Delta\tau_0\frac{T}{p}e^{\frac{E'}{RT}}\frac{1+\left(a_2\frac{T^2}{p^2}+a_3\frac{p}{T}\right)e^{\frac{E}{RT}}}{a_0+a_1\frac{p^2}{T^2}-\left(a_2\frac{T^2}{p^2}+a_3\frac{p}{T}\right)e^{\frac{E}{RT}}}. \qquad (6)$$

The equation obtained shows that *the reaction is not possible for all values of p and T*, as the denominator in (6), and, therefore, τ can take negative values in a certain area of the plane p, T. In this area no autogenetic reaction is possible. The boundaries of the possible area are defined by the relation

$$a_0+a_1\frac{p^2}{T^2}-\left(a_2\frac{T^2}{p^2}+a_3\frac{p}{T}\right)e^{\frac{E}{RT}}\geqslant 0. \qquad (7)$$

This area of autogenesis corresponds to the area of inflammation for which, according to the theory of Christiansen and Cramers, as well as that of Semenov, we have $x\delta\geqslant 1$. *However, the existing theory starts from the condition that on the inflammation boundary as well as within, the velocity of reaction takes an infinite value. Whereas our theory gives, in agreement with the experiment, a zero value for the velocity at the boundaries of the area and a finite value within the area.*

In fact, the velocity of reaction, as we have shown above, is inversely proportional to the time of retardation

$$\frac{d\alpha}{dt}=\frac{C\alpha}{\tau} \qquad (8)$$

i. e. for $x\delta\to 1$, $\tau\to\infty$ and $\frac{d\alpha}{dt}\to 0$.

When penetrating the area of inflammation, the velocity of the reaction, if the latter is maintained isothermal, increases, as will be shown below, proportional to the squared depth of penetration (at deeper penetrations the character of the dependence of the velocity on the pressure is more complex).

The experiment confirms these deductions from the theory of autogenesis, as will be seen further.

Now let us find the form of the boundaries of the autogenesis area, in other words, of the area where combustion, inflammation and explosion of the gaseous mixture are only possible *.

Equation (7) has four roots. Of them, as is easy to demonstrate, 1) one root p' is negative; 2) at least one root is positive; 3) there exists an area where the two remaining roots are also positive; 4) outside this area these two roots are complex. Let us denote the positive roots within the area $T_m\leqslant T\leqslant T_s$ through p_1, p_2 and p_3 and let $p_1\leqslant p_2\leqslant p_3$; thus, by virtue of (7), we have:

$$(p-p_1)(p-p_2)(p-p_3)\geqslant 0. \qquad (9)$$

* Naturally enough, «catalytic» combustion on the walls of the vessel is not taken into consideration.

This inequality shows that if $p < p_1$, then τ is negative, and autogenesis is impossible. At $p_1 < p < p_2$ τ becomes positive and we are within the autogenesis area. Further, at $p_2 < p < p_3$ again we obtain a negative value for τ, and only at $p > p_3$ τ again becomes positive. There we pass over the third limit and enter again the autogenesis area. Thus, we obtain a «cape» or a «peninsula» of inflammation with its peak at point p_m, T_m and a «bay» or a «gulf» reaching as low as at point p_s, T_s.

Introducing as a parameter the relative concentration

$$c = \frac{pT_m}{Tp_m} \tag{10}$$

and introducing the notation

$$c_s = \frac{p_s T_m}{p_m T_s} \tag{10'}$$

we can transform (6) (when $c_s^2 \gg 1$), giving it the form

$$\tau = \tau_0 \frac{1+z}{(c_s^2 + c^2 - z)c} e^{\frac{E'}{RT}}, \tag{11}$$

where

$$z = (1 + c_s^2) \frac{1 + 2c^3}{3c^2} e^{\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_m}\right)}. \tag{11'}$$

The equation of limits for possible combustion and inflammation will be expressed now as follows:

$$\frac{E}{RT} = \frac{E}{RT_m} - \ln \frac{c_s^2 + 1}{c_s^2 + c^2} \cdot \frac{1 + 2c^3}{3c^2}. \tag{12}$$

Assigning here to c different values we shall find the corresponding values for T and then, using formula (10), we shall find the conjugated values of p.

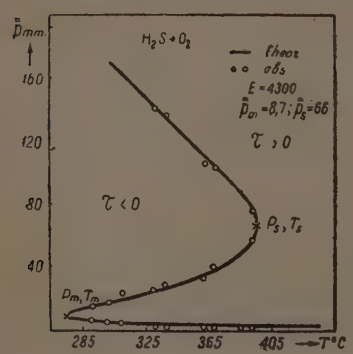

Fig. 1

The coordinates of the two extreme points are not independent in this case, but are bound by equation obtained from (12) if we accept $c = c_s$ (we can neglect unity as compared with c_s^2).

By means of this equation it is possible, when the coordinates of the extreme point of the cape and the extreme point of the bay are given, to determine and then to calculate the form of the boundaries. The results of such a computation for the limits of the area of combustion of a mixture of H_2S and O_2 are given in Fig. 1 (for 40% H_2S). In the same figure the results of the experiments of Yakovlev and Shantorovitch are referred to. The same parameters p_m, T_m and p_s, T_s determine also the character of the dependence $\tau(p)$ (the factor $\tau_0 e^{\frac{E'}{RT}}$ in this case gives only the scale of the curve). The comparison of the curve calculated according to formula (11) with the experimental curve of Yakovlev and Shantorovitch for a period of retardation, as a function of pressure within the peninsula of inflammation, has also shown a very good agreement between the courses of these curves. However, the calculated lower limit was again somewhat higher. Owing to this fact, the theoretical curve of the retardation in time was somewhat narrower than the experimental one (about 8%). Such an increase in the lower limit can be explained by the fact that a_0 and a_1 are themselves certain functions of the temperature (of the type $a_i = a_{oi} e^{\frac{E''}{RT}}$). One should refrain, however, from introducing the corresponding correction in the calculation until after the accumulation of more extensive experimental material.

As a particular case for the bay of autogenesis a simpler equation can be given. For this purpose let us substitute into (12) the value $c = c_s$, neglecting the unity as compared with c and subtracting the result of substitution from (12).

Thus, we find *

$$\frac{E}{RT} = \frac{E}{RT_s} + \ln \frac{1}{2}\left(\frac{c}{c_s} + \frac{c_s}{c}\right), \qquad (13)$$

where

$$\frac{c}{c_s} = \frac{T_s p}{T p_s} \approx \frac{p}{p_s}.$$

Simpler formulae can as well be obtained for τ within the bay. Just in this case, formula (11) gives:

$$\tau = \frac{\tau_0'}{(p - p_1)(p_2 - p)}, \qquad (14)$$

where τ_0' is constant in first approximation. Near the boundaries of the intrusion upon the area of inflammation we obtain for every point of intrusion (along the vertical line p, T on the diagram)

$$\tau = \frac{\tau_0''}{|p - p_i|}, \qquad (15)$$

where p_i is the value of the limit. A formula of that type (15) was also obtained empirically by Neuman and Egorov. The formula (14) agrees pretty well with data of Yakovlev and Shantorovitch, as may be seen from Fig. 2. In order to obtain the velocity near the boundaries of the area it is necessary to know (besides τ) the maximum value of the amount of the substance that entered the reaction. Near the lower limit we have, for instance

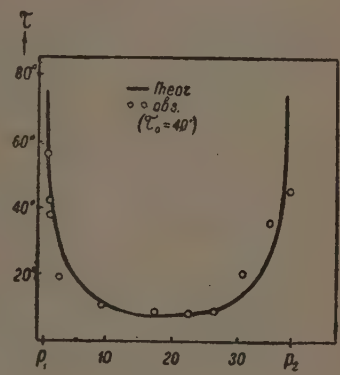

Fig. 2

$$\Delta p_{\alpha=1} = \frac{m_2 - m_1}{m_2}(p_0 - p_1), \qquad (16)$$

where m_1 and m_2 are the number of moles of the mixture before and after the reaction, and p_0, the initial pressure. For the process of combustion of the oxyhydrogen gas $m_1 = 3$, $m_2 = 2$, and thus we obtain from (8), (15) and (16):

$$\frac{dp}{dt} = \Delta p_{\alpha=1}\frac{d\alpha}{dt} = -\frac{c\alpha}{3\tau}(p_0 - p_1)^2. \qquad (17)$$

Thus, the velocity of the reaction increases proportionally to the square of the intrusion depth along the vertical. A relationship of such a kind was obtained in the experiments of Kovalsky. It shows that on the boundaries of the area of combustion, inflammation and explosions the velocity is actually zero rather than infinite.

Thus, the present theory, based on the main principles of new chemical dynamics, is free from the difficulties involved in the former conceptions and leads to the establishment of a complete shape of boundaries of the area of self-inflammation (including the three limits), as well as the dependence of the time of delay in inflammation and explosions on pressure and temperature.

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* For the lower limit, Semenov's formula ensues as a particular case from (12).

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GEOCHEMISTRY

ON GEOCHEMISTRY OF SUBTERRANEAN WATERS IN THE TARTARIAN REPUBLIC

By N. V. TAGEEVA

(Communicated by V. G. Chlopin, Member of the Academy, 15. I. 1943)

Prospecting for oil in the Tartarian ASSR has so far been guided by mainly two geological characteristics: 1) the presence of corresponding structures and 2) the occurrence along with them, in certain regions, of bitumens, both at the surface and in the profile. Nowadays, however, the oil surveyor fully realizes how important it is in searching for oil to give due attention to the chemical composition of waters associated with oil deposits. These are very typical waters; so much so, indeed, that they may claim to be named *oil-field waters*, their relation to oil being so intimate and constant as to permit the formulation of the following rule: *Any considerable deposit of oil (in regional conception), whatever the nature of the enclosing rocks, is attended by waters of a particular chemical composition. These are calcium chloride waters, brines with a high content of the elements boron strontium, radium, bromine, iodine, and with a very low content of sulphates. Waters of this kind enter as a part into the geochemical complex peculiar to the formation of oil and with all of the above-mentioned characteristics are probably encountered in no other geochemical complex. So they may be considered as indication for oil**.

From this stand-point the waters from oil-prospecting areas of the Tartarian republic were explored in 1942 for certain trace elements (or microelements)(1)**.

With reference to the chemical aspect these waters may be subdivided into two main groups: waters whose chemical composition has originated by interaction with the enclosing rocks. Such are the waters of Cenozoic and Permian formations which are widespread in and outside Tartary (2). In this group two subgroups are distinguishable: fresh, alkaline waters mainly of Cenozoic and Upper Permian origin and Lower Permian waters which are predominantly sulphate and hard-carbonate in composition. *No water of this group shows chemical features necessarily indicative of the occurrence of oil.* From their general chemical composition and the number of typical elements (B, Sr, Ra, Br, I) they may be classed with surface waters (dissolution waters and waters formed by way of

* There are a few exceptions to this rule, which are probably due to scarcity of information.

** The investigation was carried on by the author on behalf of the Petroleum Research Institute in the Waters and Rocks, Geochemical Laboratory of the Institute for Mineral Fuels, Academy of Sciences of the USSR. Part of the material studied has been kindly supplied by B. M. Epstein (Central Research Laboratory of the Tartarian Geological Trust), V. I. Baranov (from the Laboratory for Biochemical problems at the Academy of Sciences of the USSR), and E. S. Itkina (Institute for Mineral Fuels). For the hydrochemistry of natural waters of oil prospecting areas in Tartary see M. S. Kaveev, V. A. Sulin, N. V. Tageeva, B. M. Epstein, «Geochemistry of waters of prospecting areas of Tartary», 1943 (Russian), funds of the Oil Institute and the Institute of Mineral Fuels.

metathetic reactions with the enclosing rocks). Here and there, mainly in the Lower Permian (Shugurovo, Sarabikulovo, Zmievo, Tolkish and oth.), solid as well as liquid bitumens have been encountered along with small quantities of oil.

Though these occurrences speak for themselves, they probably present a secondary phenomenon in which a geochemical complex formerly associated with oil has been disturbed. In such places the presence of bitumens in the rocks, of hydrogen sulphide in waters and the general chemical aspect of the latter speak of the inflow of ordinary surface sulphide waters and of their rather short contact with bitumens.

In all structures of Tartary, where drillings have encountered Carboniferous formations, calcium chloride brines* have been disclosed in the Carboniferous which by their general chemical composition and content of typical elements (see table) belong to that genetic group, very peculiar and unique, which may properly be described as *typical calcium-chloride oil field water* and which is of the greatest interest for the petroleum hydrochemist.

The origin of this water is not yet clear. But it may probably be unveiled by experimental investigation. Such peculiar features as the accumulation of strontium, radium, bromine and iodine seem to indicate that this water has long remained in an isolated stratum of rocks amidst a favourable geochemical medi-

* Some waters encountered in Carboniferous formations at Zmievo have their salt content increased by Carboniferous brines which, however, are masked by an admixture of upper, sulphate, waters.

Summary Data on Boron, Strontium, Radium, Iodine and Bromine in Oil Waters of Tartary, of Second Baku and in Surface Brines

Waters	B		Sr		Ra	Br	I	
	grams per litre	number of tests	grams per litre	number of tests	grams per litre	grams per litre	grams per litre	number of tests
Prospected areas of Tartary { Permian	3.8×10^{-3}	14	4.5×10^{-2}	8	$n\times10^{-11}$	$n\times10^{-2}$ and <	$< n\times10^{-4}$	2
Prospected areas of Tartary { Carboniferous	3.4×10^{-21}	4	4.1×10^{-1} [11]	3	$n\times10^{-10}$ [8]	$n\times10^{-4}$	5.5×10^{-5}	—
Oil-field waters of Second Baku	$n\times10^{-3}$ [5]	—	3×10^{-1} [7]	13	$n\times10^{-10}$ [8]	$n\times10^{-9}$	$n\times10^{-8}$ [9]	—
Surface brines	4×10^{-3} [10]	19	$n\times10^{-2}$ [11]	—	$n\times10^{-12}$ $n\times10^{-11}$	$n\times10^{-11}$ $n\times10^{-3}$	$n\times10^{-11}$ and <	—

Notes: [1] According to the author, 1942. [2] Spectral analysis data by S. A. Borovick, 1942. [3] Report by V. I. Baranov and personal communication by I. E. Starik, 1942. [4] Data by B. M. Epstein and V. I. Baranov, 1942. [5] By the author for Buldyr well 3, and for V. Uslon well 4. [6] Numerous data supplied by the Mineral Fuel Institute and V. A. Sulin, L. A. Gullaeva and different oil firms, as well as author's data 1939—1941. [7] A. A. Varov and I. I. Romm, C. R. Acad. Sci. URSS, XXXVI, No. 4 (1942). [8] Value derived from an abundant material on calcium chloride oil-field waters (Radium Institute, Academy of Sciences of the USSR). [9] From a great many data obtained by the Mineral Fuel Institute and different oil trusts, V. A. Sulin, A. A. Varov, L. A. Gullaeva, 1939—1941. [10] N. V. Tageeva, On geochemistry of boron and fluorine (Russian) (in press). [11] A. E. Fersman, Geochemistry, II (in Russian).

um for the accumulation of these elements. Similarity in the proportion of the main components (say, $\frac{Na}{Cl}$, $\frac{Ca}{Mg}$ etc.) and other considerations permit to refer such waters, taken from different oil deposits of the earth surface, to a single source—the sea water, which has been preserved in the thickness of sedimentary rocks where it was subject to deep metamorphism.

In the Tartarian republic the calcium chloride brines are associated, as has been mentioned above, with Carboniferous formations. They have been met with at Verkhny Uslon 280—315 m deep under surface in the Upper Carboniferous; at Kamskoe Ustie at a depth of 115—300 m in different horizons of the Upper Carboniferous; and in the Buldyr in the Middle and Lower Carboniferous at a depth of 667—1179 m. In the Buldyr as well as at Zmievo the waters, occurring in the Upper Carboniferous, are mixed waters with increased salinity. In the annexed table the content of boron, strontium, radium, bromine and iodine is given for Permian and Carboniferous waters of the surveyed areas of Tartary for the oil-field waters of Second Baku and, by way of comparison, for ordinary brines of surface origin. It may be seen that the Carboniferous brines of Tartary differ greatly from ordinary brines in the content of these elements.

Comparisons with thoroughly explored oil deposits of the Ural-Volga region show that similar waters are here everywhere concomitant to workable deposits of oil. The structures of Tartary, as regards their general geological conditions, come nearer to the group of platform oil deposits of Second Baku (Tuymazy, Syzran), that is, to such as contain their workable oil and its typical oil-water just in their Carboniferous and Devonian formations. With regard to the occurrence of oil there is reason to surmise here the existence of a deep genetic similarity which is to be taken into account both in practical work and in pursuing the investigation in this vast region.

Thus, the basic conclusion to be drawn from the geochemical study of subterranean waters from prospected regions of Tartary is that the discovery of calcium chloride brines in the Carboniferous formations is evidence of oil occurrence here.

The assumption that oil may occur in the Carboniferous of Tartary is not new to the geologists. But it does not appear to have ever been supported by geological evidence.

From geochemical characteristics of the waters in the region investigated by us one cannot infer that oil should be also present in the Permian formations of these areas. Yet, the occurrence of workable oil in the Upper Permian rocks of the Buguruslan deposit sets before the geologists the task to investigate the geochemical conditions about that oil and take these data into account while prospecting for oil in the Permian deposits of Tartary.

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Academy of Sciences of the USSR.

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GEOLOGY

STRUCTURE OF THE PORE SPACE OF CARBONATE OIL RESERVOIR ROCKS AND THEIR PERMEABILITY, AS ILLUSTRATED BY PALAEOZOIC RESERVOIRS OF BASHKIRIA

By G. I. THEODOROVICH

(Communicated by V. G. Chlopin, Member of the Academy, 7. 1. 1943)

1. In a previous note (1) we classified the oil reservoirs, in general, and the carbonate oil reservoirs, in particular, into three main groups: those with pores more or less regularly permeable (group A), those with pores irregularly permeable (group B), and those conveying the oil along cracks and fissures (group C). Groups A and B have been subdivided by us into subgroups according to their degree of permeability; and all the three groups have been classed, moreover, according to the petrographical characters of the reservoirs. After this we confronted the task to find out the relation between the structure of the pore spaces and the petrographical character of carbonate reservoirs, on the one hand, and the permeability of these reservoirs, on the other. The material examined consisted mainly in thin-sections manufactured from columns previously tested for permeability and afterwards imbibed with coloured bakelite. The work was carried out on the Ishimbay reservoirs and partly using thin-sections from carbonate reservoirs of the Karlinsky oil-fields and from the Palaeozoic of the Tuymazy district.

2. In order to estimate the properties of reservoirs of a sandy type, P. P. Avdusin and M. A. Zvetkova have suggested two magnitudes: the effective porosity (P_e) and the hydraulic characteristics Φ. Those authors applied the above method of estimation to carbonate reservoirs, as well.

As understood by Avdusin — Zvetkova, the «effective» porosity is practically nothing else than the whole system of readily communicating (active) pores of a rock. It is certainly desirable, and in some cases even necessary, to discriminate between the two types. As a matter for regret, the classification still bears a rather conventional character being based on the evaluation of easily communicating pores. The existence of the latter may serve to evaluate the commercial capacity of a given reservoir. Another magnitude that can serve to characterize a reservoir is its permeability: from the permeability of a reservoir one can form an idea as to its percolating properties, and estimate its possible output.

If readily communicating porosity is a rather conventional characteristics, the hydraulic characteristics Φ certainly stands in need for supplementary investigation, even for reservoirs of the sandy type. It stands to reason that in loose sandy reservoirs permeability must depend on the magnitude of the wet perimeter section. However, even in more or less cemented sandy reservoirs, the conditions are more complicated because of the appearance of cement. In carbonate

reservoirs the structure of vacuity space* is still more complicated, diversified, and differs sharply from that of sandy reservoirs (see below).

3. The study of thin-sections from Artinskian and Sakmarian reservoirs of Ishimbay has shown that the degree of their permeability is mainly determined by the character of their vacuities (and the latter is accounted for by the structure of the rock and the type of the cement), by the degree of porosity and the vacuity in general, the easiness of communication, and the size of the vacuities, as well as their extension and the quantity of cement.

It has been found that an important part of carbonate reservoirs in percolation belongs to the rather isolated, more or less narrow conductive canals which serve as a communication between the separate pores; this is the first type of pore spaces. As such act also constrictions in pore spaces, which may pass more or less gradually into the pores proper, representing the second type of pore spaces. Finally, they may have the shape of narrow pores, or finely porous branch-like areas, communicating separate pores, or sometimes covering nearly the whole pore space (third type). These communications between the pores, their character, size and number, play in carbonate reservoirs a by far more important part than the length of the wet parameter of the section of the pore space. Indeed, the loss in strain by a liquid percolating through a carbonate reservoir takes place mainly when the liquid passes through narrow interstices connecting the pores, rather than when it passes through such pores as are well distinguishable on a transparent thin-section. This is especially illustrative in reservoirs whose pore spaces belong to the type I (Fig. 1). Thus, the length of the wet perimeter of the section of the pore space, as measured in a thin-section, and consequently the magnitude of Φ cannot be taken to characterize most of the carbonate reservoirs. In the case of «intergranular» percolation (IV type of structure of pore spaces) the permeability is strongly dependent upon the magnitude of the perimeter of the wet section. The magnitude of this perimeter is to a certain degree determined by the shape and surface of the grains composing the porous rock.

4. The vacuity spaces of the oil-reservoirs of the Ishimbay massives can be classed into two main types. The pore space of the first type (Fig. 1) consists of pores and of rather isolated more or less narrow conveying canals. Pores of this type are usually observed in Ishimbay reservoirs in dolomites, representing small voids after leached out detritus («negatively-detrital» dolomites). In carbonate dolomite reservoirs of other districts similar leaching-voids of an earlier cemented material are encountered at the place of oolites («negatively-oolitic» dolomites); they can also remain after fusulinides or shells of pelecipodes and other organisms. Pores of the first type are also encountered in limestones where they can be observed in the cement of the rock, at the place of very small leached out areas of the former; they can be of primary origin, corresponding to the internal cavities of skeletal remains of organisms; the latter may occasionally be practically isolated.

As a rule, the narrow canals that connect pores of the first type cannot be observed on a thin-section, their inner diameter being 0.01—0.005 mm. If the minimum diameter of a canal is larger, the canal can be detected on a transparent thin-section.

It stands to reason that neither the pores nor a structure of the first type can occur in loose sandy reservoirs; they can be met only in their cemented varieties.

5. The structure of a pore space of the second type is characterized by that the communicating ducts consist merely of constrictions in the pore space, which become wider and pass gradually into the pores proper.

This type is encountered among porous Ishimbay limestones and dolomite limestones of a detrital structure; the former contain small (or medium) amounts

* By the vacuity space of a rock and of oil reservoirs in particular we understand not only the pores, but also the caves, caverns, cracks, fissures and karst channels. Viewed at this angle, a porous space represents the most widespread variety of the void space of rocks. In other words, our interpretation of the «vacuity» of rocks is identical to that of «hollowness», as understood by F. P. Savarensky.

of calcite cement (mostly irregular scalenohedral) (Fig. 2). The latter form trims of dolomite grains around the material cemented (detritus). Among the Ishimbay dolomites pore spaces of type II are of less frequent occurrence than those of type I: they are usually observed only in certain porous dolomites with a relict biomorphic detrital structure, characterized by the presence of a thin dolomite crust.

When estimated according to our scale (1), the permeability of porous Ishimbay reservoirs with pore spaces of type II is, *ceteris paribus*, by a whole class higher than the permeability of negatively-detrital dolomites with narrow conveying ducts, invisible on a thin-section. It is nearly equal to the permeability of porous negatively-detrital dolomites with relatively wider ducts, that can partly be observed on a transparent thin-section.

Naturally enough, it is evident that loose sandy reservoirs cannot possibly be endowed with pore spaces of type II which are typical of their cemented varieties. It is of interest to note that, in spite of what has been said above, this type of structure is the main type for carbonate oil reservoirs. This is due to the fact that pores of type II, when growing less numerous in a rock, owing to the increase of space between them transform into pores of type I, as evidenced by the decrease in their permeability. This is probably accounted for by the presence in such cases of more or less narrow conveying canals between the pores.

6. Other types of the structure of vacuities are of much less frequent occurrence in the Ishimbay reservoirs.

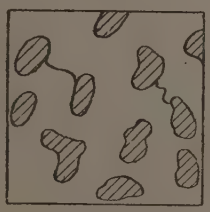

Fig. 1

Fig. 2

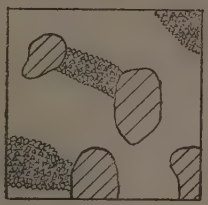

Fig. 3

Fig. 4

Symbols:

- *pores clearly observable on thin-sections*
- *fine conveying canals between pores*
- *intergranular pores*
- *fine and extremely fine-grained conveying branches*

The third type of structure is characterized by the presence of pores communicating with one another by means of finely-porous broad canals, observed on a thin-section in the form of branches (Fig. 3). In some cases the number of micropores is very small, and the whole pore space of type III represents an irregular net of fine and small porous canals, or areas communicating one with another. The conveying canals described above may occasionally be built of coarser pores, which sharply increases their permeability.

The reservoirs of type III usually correspond to dolomite; less frequently they are observed in dolomite limestones.

The fourth type of structure of pore spaces is unfrequent among the Ishimbay reservoirs; unlike this, it is typical of the main mass of the Karlinsky dolomite reservoirs and of certain Palaeozoic carbonate reservoirs of the Tuymazy district. This structure is characterized by a system of pores distributed between the grains and near the grains of the main mass of the dolomite rock or of its cement, and reflecting the outlines of the greatest part of these grains («intergranular pores»). As an example typical of most dolomites, may serve the interrhombohedral porosity shown in Fig. 4.

The fourth type of structure of pore space is encountered in two varieties: a) macroporous varieties, endowed with a good permeability (e. g. certain fine- and medium-grained dolomites from the bottom of the limestone-dolomite layer C_1^{2B} of the Tuymazy district); b) the fine-grained varieties are characterized by a medium and even high porosity, both general and communicating. At the same

time such varieties are usually poorly permeable if at all, although saturated with oil. Owing to this, they form no commercial reservoirs. The magnitude of the readily communicating pores is small and defies accurate evaluation in such reservoirs (IV, b) (see, e. g., the finely porous varieties of reservoirs of the Karlinsky oil-field).

To the fifth type of structure of vacuity space we refer the fissured reservoirs in the strict sense of the term.

And, finally, under the type VI as a mixed one we class such reservoirs as are characterized by two (or more) elementary types of the structure of their vacuities. As an example may serve the finely porous and fissured dolomite reservoirs of the Karlinsky oil-field.

Among the cemented reservoirs of a sandy type there may occur varieties whose vacuities display any of the structures described above under type III, IV, V or VI.

We have described in this note the main types of the structure of the vacuity space of all the carbonate oil reservoirs known by us in Bashkiria.

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GENETICS

FREQUENCY OF MINUTE REARRANGEMENTS AS DEPENDENT UPON THE DEGREE OF HETEROCHROMATIZATION OF THE CHROMOSOME SECTION INVOLVED

By M. L. BELGOVSKY and A. A. PROKOFYEVA-BELGOVSKAYA

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Prokofyeva-Belgovskaya's ([1]) cytological studies of a series of invertions and translocations, involving heterochromatic regions, have shown that euchromatic sections when brought into immediate vicinity of heterochromatic regions assume a structure similar to that of the latter. This process of «heterochromatization» consists in a disturbance of the normal chromosome conjugation and in an increase in the amount of thymonucleic acid in the chromosome. Along with the heterochromatization of the euchromatic sections adjoining the heterochromatic regions, there occurs a change in the mode of the action of these sections on the development of the organism. This change is manifested in a mosaic development of characters, depending upon the genes located in the section in question. Cytological investigations by Prokofyeva-Belgovskaya have shown that the degree of mosaicism proves in such cases positively correlated with the degree of heterochromatization. The frequency of hereditary changes of characters depending upon the genes, located in those sections which become heterochromatized, is thereby increased, the changes observed being apparently connected mostly with minute rearrangements in the corresponding chromosome sections ([2–4]). An especially sharp increase is shown by the frequency of *y—ac* «mutations» in the sc^8 chromosome, where it proves to be about ten times as great as in the normal chromosome.

Two explanations of this increase of the minute rearrangement frequency are theoretically possible.

First, it may be suggested that heterochromatization of a chromosome section renders it more liable to breaks.

Secondly, the increase in the rearrangement frequency near the heterochromatic regions may result from a mere increase for a given euchromatic region of the possibility of its participation in a rearrangement, the absolute frequency of breaks within it remaining unchanged. In fact, the frequency of breaks in heterochromatic regions being higher than in euchromatic ones, any break in an euchromatic section approximated to the heterochromatic one will more frequently coincide with another break in its vicinity than it would in the case of the section in question lying near an euchromatic region (this statement is equally true irrespective whether the two breaks are independent or interconnected and due to a common cause). This would lead to a higher probability of recombination of the broken ends in the first case as compared with the second.

In order to find out whether the increased mutability of a given chromosome section is a result of this section's heterochromatization, or of the mere fact of its location near the heterochromatic region highly liable to breaks, we determined the frequency of «mutations» in the *y—ac* section of the sc^8 chromosome,

at different degrees of this section's heterochromatization. We used sc^8Bw^a males from a homozygous stock, and similar males from an attached X stock. In the first case the males received their X-chromosomes from their mothers, while in the second—from their fathers. According to Noujdin's data, the degree of mosaicism in such males is different: 0.69% of mosaic males in the homozygous stock and 13.75% in the attached X-stock.

A parallel cytological study of salivary gland chromosomes of males of both these types showed the following.

The peculiarity of the structure of the left end of the chromosome, consisting of a distal heterochromatic section 1A123, followed by an euchromatic one—1A45B-1 (y—ac), and then again by a heterochromatic section 20AB-1, leads to an extremely high physiological lability of the whole region. One can observe, in one and the same larva, nuclei with a completely euchromatic (typical discoidal) structure of the region in question, along with nuclei in which it is completely heterochromatic (a typical chromocentral structure), and finally nuclei with intermediate conditions between these two extremes. The per cent of heterochromatization of the y—ac section, the relative frequency of nuclei with heterochromatic or euchromatic condition of the section in question is, however, constant for every stock studied.

The data of a cytological investigation of sc^8 males of different origin are presented in Table 1.

Table 1

Per cent of Heterochromatization of the y—ac Section in sc^8Bw^a Male Larvae

Stock	Number of nuclei investigated	Number of nuclei with euchromatic condition of the $y-ac$ section	%	Number of nuclei with heterochrom. condition of the $y-ac$ section	%
sc^8 ♀ × sc^8 ♂	100	62	62	38	38
$\widehat{yy}$ ♀ × sc^8 ♂	50	14	28	36	72

This table shows that the per cent of heterochromatization of the y—ac section is much higher in sc^8 males which received their X-chromosome from their fathers (72%) than in males, which received it from their mothers (38%).

In order to compare the frequency of mutations in the germ-cells of the males of both these types, such males were simultaneosusly X-rayed (the dose being 3000 r), and then crossed to $y\ ac\ v$ females. In F_1 the frequency of y and y—ac «mutations» was recorded. The treated males were transferred into fresh bottles with virgin females every six days, and thus three breeds of offspring were produced. This was done in order to find out whether the age of the germ-cells exerts any influence on the frequency of the changes studied. The results of the nine X-raying experiments carried out are presented in Table 2.

The number of flies in the two series compared having been not always equal, the estimation of the average «mutation» frequencies and their comparison were performed with the aid of the method recently proposed by Muller (5) for the evaluation of the significance of differences obtained by averaging essentially different series.

The average «mutation» frequency thus estimated for all three broods of the $sc^8 \times sc^8$ stock is 0.00167, while for the $\widehat{yy} \times sc^8$ stock it is 0.00118. The ratio of the difference between these two frequencies to its own standard error is 2.51. A comparison of the average frequencies found in different broods shows that the differences between these frequencies decrease from the first brood to the third one.

Table 2

Frequency of *y* «Mutations» in sc^8 from $sc^8 \times sc^8$ and $sc^8 \times \widehat{yy}$ Stocks

Series	Brood	$sc^8 \times sc^8$ (*A*)			$sc^8 \times \widehat{yy}$ (*B*)		
		number of flies	number of «mutations»	«mutation» frequency p_A	number of flies	number of «mutations»	«mutation» frequency p_B
1	1	4882	8	0.00164	5577	9	0.00161
2	1	6415	17½	0.00273	3091	5	0.00162
3	1	7356	15	0.00204	8245	7½	0.00091
4	1	3070	1	0.00033	3399	1	0.00029
5	1	3794	7½	0.00198	5660	0	0.00000
6	1	2075	3½	0.00170	537	4	0.00745
7	1	3557	18	0.00505	2750	5	0.00182
8	1	618	2	0.00324	564	1	0.00177
9	1	2383	4½	0.00191	1996	2	0.00100
Total	1	34150	77		31819	34½	
1	2	2334	7	0.00300	3104	7	0.00226
2	2	7254	16½	0.00227	3776	5	0.00132
3	2	3896	13	0.00334	6633	19	0.00286
4	2	2153	2	0.00093	2347	2	0.00085
5	2	4156	6½	0.00156	4015	1½	0.00037
6	2	764	0	0.00000	860	7	0.00815
7	2	1188	1½	0.00126	1298	5	0.00385
8	2	883	2	0.00226	840	0	0.00000
9	2	608	1	0.00164	1174	1	0.00085
Total	2	23236	49½		24047	47½	
1	3	4424	1	0.00023	4414	0	0.00000
2	3	4844	2	0.00041	4957	0	0.00000
3	3	4471	2	0.00045	3743	2	0.00053
5	3	3306	1	0.00030	3352	0	0.00000
7	3	2686	0	0.00000	2137	4	0.00187
8	3	413	0	0.00000	472	0	0.00000
9	3	608	1	0.00165	760	½	0.00066
Total	3	20752	7		19835	6½	
Grand total		78138	133½		75701	88½	

In the first brood the corresponding frequencies ($\bar{p}_A$ and $\bar{p}_B$) are equal to 0.00218 and 0.00121, $\frac{\text{Diff}}{m_{\text{Diff}}}$ being 3.03; in the second brood $\bar{p}_A=0.00217$, $\bar{p}_B=0.00182$, and $\frac{\text{Diff}}{m_{\text{Diff}}}=0.83$; in the third brood $\bar{p}_A=0.00032$, $\bar{p}_B=0.00034$, and $\frac{\text{Diff}}{m_{\text{Diff}}}=0.11$. Consequently, the frequency of «mutations» in the sc^8 males derived from the $sc^8 \times sc^8$ stock is during the first six days significantly higher than in the sc^8 males from the attached *X*-stock. The difference between the frequencies of the next six-day-period is already insignificant, while the frequencies of «mutations» occurring from the 13th to the 18th day are decidedly equal.

These data show that a difference in the degree of heterochromatization of the *y*—*ac* section influences the frequency of «mutations» in it. They, further, show that the frequency of «mutations» is higher in the *X*-chromosome of males from $sc^8 \times sc^8$ stock, in spite of the low degree of this chromosome's heterochroma-

tization. And, finally, they show that the effect of heterochromatization is instrumental only in the first portions of the sperm of males from the stock compared.

The fact of a lower «mutation» frequency in the *X*-chromosome of males from the attached *X*-stock shows that the increase of heterochromatization under the influence of some intracellular conditions does not lead to an increase of mutability. The increase of mutability of euchromatic sections when approached to heterochromatic regions presumably depends not on the heterochromatization of such sections, but on the increase of the probability of coincidences of any break occurring within them with other breaks in their vicinity. As one can see from a comparison of the «mutation» frequencies of the first six days, an increase of heterochromatization *per se* does not increase the frequency of «mutations» in the section affected, but decidedly reduces it. The cause of this decrease may, of course, be but vaguely suggested. It seems not improbable that an increased amount of thymonucleic acid, enveloping the chromonemata, may to some extent prevent the recombination of the broken ends and thus decrease the frequency of rearrangements in a given region.

Structure of the left end of the sc[8] chromosome: *a*—*b*, the section 1AB-1 in a heterochromatic condition; *c*, the section 1AB-1 in an euchromatic condition

However, attention must be called to the fact here established of the absence of a positive correlation between the degree of mosaicism and the frequency of hereditary changes of the same character in the stocks compared. This fact presents an additional argument against the explanation of the changes, taking place in somatic cells and leading to mosaicism, in terms of mutations (in the broad sense of the word).

The disappearance of a difference in the «mutation» frequency in the second and the third broods shows that the difference in the condition of heterochromatized chromosome sections, which originates in the organisms of the male and of the female and does not vanish till the stage of the mature germ-cells of the next generation, does nevertheless gradually diminish, eventually disappearing completely. Thus, the chromosome changes in question prove reversible.

Considering the relative frequency of «mutations» in the germ-cells of different age, we see that this frequency sharply decreases when we pass from mature to immature germ-cells. The average «mutation» frequency in the first broods of both stocks compared is 0.00184, while in the third brood it is only 0.00036; $\frac{\text{Diff}}{m_{\text{Diff}}}=6.43$. The corresponding values obtained when comparing the second broods with the third ones are 0.00211 and 0.00052*, $\frac{\text{Diff}}{m_{\text{Diff}}}$ being 6.36. It can thus be pointed out that the regularity established for point mutations and gross rearrangements holds equally true for minute rearrangements.

Institute of Genetics.
Academy of Sciences of the USSR.

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* The inequality of the average «mutation» frequencies in the third brood, when data pertaining to it are compared with those of the first and, correspondingly, of the second brood, depends upon using in these two comparisons different weights, the latter being influenced by the total numbers of flies and the numbers of «mutations» in the broods compared.

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BOTANY

CELL DIVISION IN BUDS OF SHRUBS DURING WINTER

By S. V. VICTOROV

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The hibernal growth of buds in trees and shrubs has been treated less thoroughly in botanical literature than the rest of physiological processes whose course during winter has been studied rather in detail. The mere possibility of winter-growth was originally altogether refuted. Thus, in his «Philosophy of zoology» Lamarck considers winter-rest as a period of complete stop of a number of most important functions of a plant, inclusive of their growth. Mohl (5) and De Candolle (2) likewise refuted the possibility of winter-growth of buds in woody plants. Such an attitude towards winter-growth can be encountered even nowadays (6).

The first to point out the possibility of winter-growth was Senebier (7), but it was Geleznoff who gave the first detailed description of this phenomenon (3). According to this author's observations, hibernal growth proceeds continuously throughout the winter, stopping only at the time of the most violent frosts and recommencing as soon as weather grows warmer again. Geleznoff ascribed an important rôle not only to prolonged thawing, but to short warming of woody plants by the midday sun at clear frosty days. Later on ideas related to those of Geleznoff were suggested by Askenasy (1) and, independently of the work of Geleznoff, by Mangin (4).

All the authors listed above evaluated winter-growth after the variations in the mean weight and size of the buds, and after the morphological alterations taking place in the latter.

The present work has been undertaken in order to clear whether or not cell division as one of the forms of winter-growth takes place in wintering buds of some shrubs. The work was carried out in autumn and winter 1939—1940 and 1941. As material several varieties of gooseberry were used. This note contains data concerning two varieties, «Brazil» and «English green».

The buds were treated with Carnois's fixative within the period from September to May, every five days, and sometimes at shorter intervals. Fixation was practised under field conditions. After the preparations had been manufactured and stained with haematoxylin after Heidenhain, I counted the number of mitoses (the total number of mitoses and that for each phase separately). Along with this, records were taken of the mean morphological state of the various parts of the flower, typical of the bud as fixed at a given day, as well as of temperature and air humidity. In order to bring out the influence of the snow cover upon the buds, those of them that were immersed in the snow were fixed apart from the buds that remained uncovered.

Among the whole material examined there was not one bud that would show a total lack of mitoses. Even in such buds that were fixed on January 16, 1940 at a temperature below—40° C, there were found from 50 to 57 mitoses per bud.

During November—December 1940 the number of mitoses per bud varied from 105 to 222 (in the variety «Brazil») and about 100 (in «English green»).

Part of the mitoses (especially of those that were observed at the lowest temperatures) might have been stopped at a certain phase. It seems, however, scarcely probable that the mitoses stop altogether during winter, for the average number of mitoses in buds varies in the course of winter months, which points to an alternating revival and extinction in the processes of cell division. And this naturally precludes the idea of a total stop of mitoses during winter.

So far as one can judge by the average number of mitoses observed, the intensity of cell division is not the same in the two varieties. In «English green» the number of mitoses decreases gradually at the approach of winter; we failed, however, to establish a pronounced winter-minimum. In spring, from the beginning of March, the number of mitoses increases sharply. In the variety «Brazil» the number of mitoses is rather small during the first half of autumn (no more than 100 per flower). In November-December their number increases almost twice (from 105 up to 222); in January-February the number of mitoses drops sharply again and gradually augments with the approach of spring. During winter 1939—1940 an especially well pronounced minimum was observed, which was possibly due to the violent frost.

There could be noticed no appreciable increase in the dimensions either of the buds or of any parts of the flower in the course of winter.

During winter-thawing neither of the gooseberry varieties showed any increase in the number of mitoses.

The difference between those twigs that were sheltered by snow and those exposed to the cold consisted largely in the number of the buds injured by frost. As to the number of mitoses in buds unprotected and protected with snow, they showed no differences. Apart stand buds of those sprouts that lay upon the very ground and were partly covered with soil during the autumnal loosening around the shrub. By the number of mitoses, size, as well as by the rate of development, those buds considerably excelled the buds in any other part of the shrub.

From all that has been said above the following conclusions can be drawn:

1) The process of cell division in buds continues throughout the winter. A certain part of the mitoses may possibly be inhibited by the cold, which breaks their normal progress.

2) The intensity of cell division varies as to the period of winter-rest.

3) The intensity of winter division of cells varies in the course of winter not in the same way in different plant varieties.

4) Winter-growth of buds can to a certain degree be stimulated by covering the sprouts with soil; this observation can be turned to profit in agricultural practice.

Institute for Cytology, Histology and Embryology.
Academy of Sciences of the USSR.

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MICROBIOLOGY

EXPERIMENTAL INOCULATION OF MUTANTS OF *MYCOBACT. LEPRAE* KEDROWSKII TO WHITE MICE MADE SENSITIVE WITH SKIN EXTRACTS*

By ANNA J. JOLKEVICH

(Communicated by N. F. Gamaleya, Honorary Member of the Academy, 30. X. 1942)

V. I. Kedrowsky succeeded in isolating in 1901—1902 a remarkable acid-susceptible lepra culture. When injected subdurally this culture induced in a rabbit leprosy; in the organism of the animal the microbe of lepra passed from the condition of susceptibility to the acid to that of resistivity. From the infected rabbit Kedrowsky isolated two main virulent cultures, an acid-susceptible and an acid-resistant. Kedrowsky's acid-susceptible culture existed but a short while; the acid-resistant culture lost its virulence soon. All attempts made by Kedrowsky in order to make it acid-susceptible again proved a failure. I subjected Kedrowsky's acid-resistant *Mycobacter* to combined treatment with an aqueous emulsion of chaulmoogra-oil and with X-rays; as a result I obtained an acid-susceptible mutant No. 30/2. This mutant has been preserved now during 3 years; morphologically it is much alike the acid-susceptible diphtheroid culture that had been isolated by Kedrowsky in 1901 from a rabbit affected with leprosy (1).

As a result of a repeated exposure of the acid-susceptible achromogenic culture No. 30/2 to X-rays I obtained a new, intensely pigmented acid-resistant mutant No. 241 that seggregated from the diphtheroid culture No. 30/2.

When injected to mice intravenously, the diphtheroid culture No. 30/2 proved biologically active.

The diphtheroids survived in the organism for a long period of time, provoking loss of hairs, cutaneous ulcers on the sacrum, tumours on the extremities and mutilation of the toes. Smears taken from the affected skin areas, as well as from lymphatic glands, spleen, testes, showed the presence of diphtheroids.

One could see them pass from an acid-susceptible condition to the acid-resistant condition.

Along with diphtheroids the smears showed isolated acid-resistant bacilli and elegant streptobacilli that stained after Ziehl-Nielsen. On account of the fact that culture No. 30/2 showed itself particularly active with respect to the skin, in which it was analogous to the dermothropic lepra bacilli, we undertook to make the skin of mice sensitive by injecting them intravenously our diphtheroid culture. The injections were practised 6 times at 2—3 day intervals.

* Reported at the meeting of the Department for leprosy control, held at the Central Institute of Malaria and Medical Parasitology on May 12, 1941.

After this the skin was depilated on the thorax and abdomen, cut off, washed from the outside with a 10% solution of sulphuric acid, rinsed with saline, ground and steeped in salt solution on ice for 2—24 hours. The extract obtained was filtered through a paper filter and could also be passed through a Seitz filter.

The suspension of the young diphtheroid culture was then put together for half an hour with the filtrate, after which it was introduced to fresh mice intraperitoneally.

For intravenous injections we used mostly the culture, while the filtrate was used for intraperitoneal injections.

One-two weeks upon inoculation the mice began to perish. Those of them which had been infected intraperitoneally developed tumour-like nods, those treated intravenously displayed acute experimental tuberculosis with formation of numerous milliary and submilliary nodules. A histological examination of the nodules showed the presence of granulomas, consisting of epithelial cells whose cytoplasm was a honeycomb-like structure. The central part of the granulomas underwent rapid necrosis. In the necrotic masses, as well as in the epithelial cells, there were scattered diphtheroids. Along the periphery of the necrotic zones, at the boundary with unaltered cells, the diphtheroids were accumulated in such huge numbers that, when viewed under a microscope at feeble magnification, the picture was that of a felt-fabric.

There are many infections that assume either an acute, or a chronic course.

It is beyond any doubt that leprosy may, like tuberculosis, proceed as an acute disease; in such cases, however, the disease fails to be discriminated. And it is not until many years have passed, in the case the disease has assumed a chronic course and the central nervous system is affected, that the diagnosis becomes obvious; the microbe acquires acid-resistant properties and is identified by us as the classical Hansen bacillum.

The acid-susceptible growth that originated from the acid-resistant culture of *Mycobact. leprae* Kedrowskii may possibly induce in the sensitivized mice under the mutogenic influence of X-rays an acute form of the disease which is usually overlooked in the clinique of the leprosy, and remains unidentified.

When infecting the mice with the chromogenic acid-resistant mutant No. 241, obtained from the diphtheroid mutant No. 30/2 of Kedrowsky's *Mycobact. leprae* by exposing it to the effect of X-rays, we applied the procedure described above.

The mice were made sensitive with culture No. 241 which was introduced intravenously 6 times at 48-hour intervals.

From the skin of the thorax and abdomen an extract was prepared, which was used within 24 hours upon preparation.

The animals were inoculated a young culture of No. 241 which was injected to healthy white mice simultaneously with the skin extract.

Out of the 27 mice infected 22 became ill; the process was generalized in 16 mice, viz. in 59.2%. The disease assumed a subacute course and lasted from 2 weeks to 3 months. In the case of intraperitoneal infection there was development of coarse nodules that reached the size of a lentil seed. In the case of intravenous infection, milliary and submilliary nodules appeared in the peritoneum, lining the anterior and posterior wall of the abdominal cavity and of the diaphragm, in the mesentery, the epiploon, liver and spleen.

Histological examination has shown that the formation of young nodules takes place against a background of such alterations as are typical of allergic reactions of the connective tissue. There is observed fibrinoid swelling with subsequent development of fibrinoid necrosis of the connective tissue, and infiltration of the round cells. This is followed by the development of epithelioid cells which gradually assume the character of Wirchow's foamy cells. The central part of large nods undergoes nectrosis. The necrotic zone is surrounded with a zone consisting of cells in a state of necrobiosis. Karyorhexis and pycnosis of the

nuclei are well expressed. In this zone, closer to the necrotic one, there is calcification.

Outside the necrotic zone are situated cells with polymorphic nuclei. The next zone consists of large cells with abundant foamy protoplasm of the type of Wirchow's cells, pathognomonic for leprosy. These are followed by a zone of densely packed histocyte elements, among which there are epithelial cells, oval and elongated in shape, and fibroblastic cells. Farther lies the zone of elongated cells of the connective tissue. The cells with a light foamy protoplasm contain abundant lipoid inclusions. In the centre of the nods there occur numerous acid-resistant bacilli.

These become less numerous in the zone of polynuclear and necrobiotic cells.

In the zone of the light foamy cells the number of acid-resistant bacilli increases again. In the protoplasm of the foamy cells there are encounte red individual bacilli or groups of them. Acid-resistant bacilli are likewise encountered in the epithelial cells occupying the periphery of the zone of foamy elements.

When stained after Gram-Much, the number of gram-positive microorganisms that stain as grains or granular rods exceeds that of bacilli that stain after Ziehl-Nielsen.

Two of the mice infected intravenously showed a well expressed thickening of the hind extremities, loss of hair, ulcerations on the hips and on the hind surface of the feet, and mutilation of toes. Histological examination of their skin revealed fibrinoid swellings and foci of fibrinoid necrosis. The latter were surrounded with cells containing polymorphous nuclei. Among the swollen collagenous fibrillae there were inclipped large cells filled with clear foamy protoplasm, containing lipoidal inclusions. When stained after Ziehl-Nielsen, the necrotic foci are found to contain a great number of acid-susceptible grains and granular bacilli, among which individual acid-resistant rods and streptobacilli are encountered.

The acid-resistant bacilli are occasionally scattered along the vacuities of the tissues and lie between the collagenous fibrillae. The protoplasm of foamy cells containing lipoids includes up to ten acid-resistant bacilli. From the multitude of acid-susceptible bacilli found in the necrotic foci one is led to assume that the microbes of leprosy multiply intensely during the acid-susceptible stage in the organism of the mouse. When examining the structure of nods from the liver and spleen we found in a number of cases the formation of young nods along the periphery of the large nod. And while the necrotic masses of the large nods are so rich in acid-resistant bacilli that when viewed under a microscope with a dry system their accumulations look like a felt-fabric, the young nodules, formed along the periphery of an old nod, contain acid-susceptible bacilli alone. It should evidently be assumed that in the process of evolution of a nod the number of lipoids increases along with the development of the necrotic processes.

Having encountered an appropriate medium, the microbe becomes acid-resistant.

Kedrowsky ([2]) has laid particular stress upon the ability of the agent of leprosy to induce, like the agent of tuberculosis, necrotic alterations in the tissues.

Necrotic alterations in nods have been described in all his experiments, involving inoculation of rabbits through the lymphatic system.

The structure of nods observed in the mice inoculated with the culture No. 241 upon treatment with cutaneous filtrates is analogous to that in rabbits affected with leprosy as a result of Kedrowsky's experiments.

Conclusions

1) Extracts from the skin of mice made sensitive to X-ray cultures of Kedrowsky's *Mycobact. leprae* are apt to enhance the susceptibiliiy of healthy mice to the infection with these cultures.

2) When white mice are infected with the acid-susceptible mutant No. 30/2 of Kedrowsky's *Mycobact. leprae* along with an extract prepared from the skin of animals made susceptible to this culture, the mice develop an acute form of the disease. The latter assumes the form of acute experimental tuberculosis, different from the disease reported by Kedrowsky.

3) When white mice are injected with a culture of the acid-resistant chromogeneous mutant No. 241 of *Mycobact. leprae* Kedrowskii along with an extract, prepared with the skin of animals made susceptible to this culture, the mice develop a disease which assumes a subacute course. The disease is analogous to the lepral affection, as brought about by Kedrowsky in his experiments.

Department of Lepra-Control.
Central Institute of Malaria and Medical Parasitology.

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